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Research Article

Cardiovascular Health Is Associated With Physical Function Among Older Community Dwelling Men and Women

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Abstract

Background: Age related decline in physical function is a significant concern affecting the quality of life of older individuals.
Methods: We examined the associations between baseline overall cardiovascular health (CVH), its components, and physical function in 906 men and women from the InCHIANTI cohort. Physical function was assessed using the Short Performance Physical Battery and poor physical function was defined as an Short Performance Physical Battery score less than 10. Overall CVH score, ranging from 0 to 12 in the cohort, was operationalized using adherence to ideal levels for health behaviors including smoking status, physical activity, body mass index, and diet quality; and health factors including blood pressure, plasma cholesterol, fasting blood glucose, with higher scores indicating better CVH.
Results: Mean age at baseline was 74 (*SD* = 6.7) years and 55% were women. At baseline and over 9 years, as compared to the lowest tertile of overall CVH score, the highest tertile was associated with a 69% ($p < .001$) and 63% ($p < .001$), respectively, lower risk of poor physical function. Among the CVH components, adherence to ideal levels of health behaviors was more strongly and consistently associated with lower odds of poor physical function than health factors.
Conclusions: Better overall CVH was protective against poor physical function in community-dwelling men and women aged 65 years and older. Improving CVH may be instrumental in the prevention of poor physical function in older adults.

Keywords: Life's simple 7—InCHIANTI study—Short physical performance battery—Physical performance

The worldwide population of those 65 years and older is rapidly growing (1). In the United States, the proportion of this age group has increased by 21% from 2002 to 2012 (2). The ability of older individuals to live independently as well as maintaining their quality of life is a pressing public health concern. Declines in physical function can lead to a loss of independence and a poor quality of life (3). Additionally, loss of physical function is also associated with extended hospital or nursing home care (4), declines in cognitive function (5), an increased risk of disability (6), and a higher risk for mortality (7). It is therefore imperative to understand the possible reasons for declines in physical function among older individuals to develop effective prevention strategies for functional declines and maintaining their quality of life as they age.

Lifestyle and health factors have been shown to be associated with physical function among older individuals (8,9). Lack of physical activity, being overweight, smoking and consuming a poor quality diet are all associated with higher risk of mobility disability and poor physical performance (10–14). Presence of chronic diseases such as diabetes and hypertension have also been linked with a faster functional decline (15,16). Most previous studies have examined the associations between physical function and individual lifestyle and health factors, and those that have used overall measures have included only three or four lifestyle factors (8,9). In addition, few, if any, investigations have specifically accounted for multiple risk factors in their analyses which is critical in older adults who generally present with multiple co-morbidities.

In 2010, the American Heart Association (AHA) released their 2020 impact goals, "to improve the cardiovascular health of all Americans by 20% while reducing deaths from cardiovascular diseases and stroke by 20%" (17), and put forth a metric, termed Life's Simple 7 (LS7) to assess and monitor the progress of the U.S. population towards these impact goals (18). Several epidemiological investigations have also examined its associations with cardiovascular disease and stroke morbidity and mortality (19–21). Since this metric includes lifestyle factors including smoking status, physical activity, body mass index (BMI), and diet quality, and health factors including blood pressure, plasma total cholesterol and fasting plasma glucose which are also associated for overall health and well-being; we proposed to examine whether an overall cardiovascular health (CVH) score based on the LS7 metric and its components at baseline, was associated with physical function in a community dwelling cohort of older individuals. We hypothesized that higher scores at baseline, indicating better CVH, would be associated with better physical function.

Methods

Study Population

This study used data from the InCHIANTI cohort, a prospective population-based longitudinal study designed to investigate reasons for mobility–disability among older individuals. Participants were randomly selected from the population of two cities, Greve in Chianti and Bagno a Ripoli, in Tuscany, Italy, through a two stage stratified sampling procedure in 1998–2000. Data were collected through home interview, a medical exam and physical performance assessment at the study clinic, as well as 24-hour urine and blood tests. The follow-up visits were conducted approximately 3 years (2001–2003), 6 years (2004–2006), and 9 years (2007–2009) from baseline. A more detailed description of the InCHIANTI study procedures has been provided elsewhere (22).

Out of the 1,453 participants recruited at baseline, we excluded 287 participants who were less than 65 years of age. Additional exclusions included participants who were diagnosed with dementia at baseline (n = 82), participants with implausible reported energy intakes (daily energy intakes below 600 kcal or above 4000 kcal, n = 14) and those with BMI less than 18.5 kg/m^2 at baseline (n = 4). A further 160 participants with missing information on baseline physical function or components of LS7 were excluded from the study, leaving an analytical sample of 906 participants at baseline. Of these, at 3-, 6-, and 9-year follow-ups, the number of participants with complete information on physical function was 692, 604, and 443, respectively.

Physical Function

Physical function was assessed by Short Physical Performance Battery (SPPB), an objective assessment which includes three physical performance tests: 4-meter walking speed, repeated chair stands, and standing balance, each assigned a score of 0–4 depending on performance (23). The 4-meter walking test was assessed for participants at their usual pace through the 4-meter walking course. The faster time of finishing 4-meter course from two walks was used for scoring. During repeated chair stands test, participants were asked to stand up from a sitting position five times, and the score was based on the total time used. For standing balance test, participants were asked to stand in three positions for 10 seconds from easy to hard: side-by-side stand, semi-tandem stand, and tandem stand. Participants who were unable to complete either task were given a score of 0. The overall score on the three tests was then calculated as the SPPB score, ranging from 0 (worst physical function) to 12 (best physical function). A cut-off for SPPB score of less than 10 was used to indicate poor physical function (23,24).

Overall CVH Score

CVH was based on the AHA LS7 criteria, comprising seven health factors and behaviors including smoking status, physical activity, BMI, diet quality, blood pressure, total cholesterol, and fasting plasma glucose (17). Depending on their conformance to the AHA criteria, for each behavior or factor, participants were given a score of 0 (poor), 1 (intermediate), or 2 (ideal). The detailed criteria for classification of each component in this cohort are provided in Supplementary Table 1.

We modified the criteria for the physical activity component based on data available for the cohort. Physical activity was classified as inactive which included inactivity or some walking; light active, which included light exercise 2–4 h/wk and; active, which included light exercise for more than 4 h/wk, moderate exercise for at least 1–2 h/wk, or intense exercise many times/week (14). For diet quality, we have previously demonstrated that adherence to a Mediterranean-type diet in the cohort was associated with frailty and physical function decline (14,25). Also, given the location of the cohort, a Mediterranean-style diet was more consistent with their general dietary pattern. Therefore, we used adherence to Mediterranean-style diet to assess diet quality (26). Diet data were collected by food frequency questionnaire developed for Italy site of the European Prospective Investigation on Cancer and Nutrition study and previously validated in the InCHIANTI cohort (27,28).

Information on smoking status was collected at home interview. BMI (in kg/m^2) was calculated using measured weight (in kgs) divided by height (in m^2). Blood pressure was measured with standard mercury sphygmomanometer in supine position. The value of blood pressure used for analyses was the average of the last two measures on the arm with higher systolic blood pressure at the first measure, with an interval of 2 minutes between the measures. Total cholesterol and fasting plasma glucose were obtained from commercial enzymatic tests (Roche Diagnostics), and an enzymatic colorimetric assay using a modified glucose oxidase-peroxidase method and a Roche-Hitachi 917 analyzer (Roche Diagnostics, GmbH, Mannheim, Germany), respectively, on the blood sample collected when participants were at least 8-hour fasting. Information on medication use was obtained during home interview.

Covariates

Other variables including age, sex, years of education, impaired cognition, presence of chronic diseases, and depression were used as covariates in the model. Cognitive status was assessed by Mini Mental State Examination (MMSE) score (0–30), and participants who had a score below 24 was classified as having impaired cognition (29). Chronic disease status (modeled as Present/Absent) was assessed based on the criteria used in the Women's Health and Aging Study, and included cancer, heart failure, coronary heart disease, stroke, chronic lung disease, hip arthritis, liver disease, gastrointestinal disease, peripheral arterial disease, Parkinson's disease, and renal disease (30). Center for Epidemiological Studies-Depression (CES-D) scale was used to assess depression, and participants with score greater or equal to 20 were classified as having depression (14).

Statistical Analyses

Tertiles of the overall CVH score in the cohort and adherence to ideal, intermediate, and poor levels of individual CVH components were used for analysis. The 1st, 2nd and 3rd tertiles in the cohort had scores ranging from 0 to 6, 7 to 8, and 9 to 12, respectively. Descriptive characteristics were reported as mean ± standard deviation (*SD*), percentage, or median (interquartile range), and the differences of baseline characteristics across tertiles were assessed using one way ANOVA, Chi-square test or Kruskal–Wallis test, respectively. Logistic regression was used to examine the associations between poor physical function and overall CVH score at baseline, adjusting for covariates. Longitudinal associations were examined using generalized estimating equations (GEE) models with unstructured correlation, adjusting for covariates at baseline. All covariates were selected based on univariate analyses and published literature on physical function. Analysis of individual health behaviors and factors were mutually adjusted for each other, in addition to the covariates. All longitudinal analyses were confirmed by mixed effects models. Associations between health behaviors and factors and each SPPB component were also analyzed separately with adjusted GEE models. Given the potential effect of stroke and heart failure on the SPPB test, we conducted sensitivity analysis excluding participants with stroke or heart failure at baseline. We also examined effect modification by time, age, and sex on the associations between CVH and poor physical function by including a multiplicative term in the model. Since these terms were not statistically significant ($p > .05$), we excluded them from the model. All analyses were performed with Stata version 13 (Stata Corp, College Station TX), and p-value less than .05 was considered statistically significant.

Results

The baseline characteristics of the study population are shown in Table 1. The overall CVH score in the cohort ranged from 0 to 12. The mean age of the cohort was 74 years ($SD = 6.7$), and 55.3% of participants were women. Participants with higher overall CVH scores had a lower number chronic diseases ($p < .001$) and although the difference was not statistically significant, those with higher CVH scores were younger ($p = .079$). In the cohort, individual components of the CVH were significantly associated with tertiles of the overall score, wherein, the highest tertile of CVH score, indicating better CVH, was associated with a higher proportion of nonsmokers, higher levels of physical activity, adherence to a Mediterranean-style diet and lower BMI (all $p < .001$). In addition, better CVH health was also associated with lower levels of blood pressure, fasting plasma glucose, and total cholesterol. The percent of poor physical function was inversely associated with increasing tertiles of CVH health.

At baseline (Table 2), for the fully adjusted model, a one unit increase in the overall CVH score was associated with 24% lower

Table 1. Baseline Sociodemographic and Health Characteristics by the Tertiles of Overall Cardiovascular Health Score Among InCHIANTI Participants Aged 65 years and Older

	Total	Overall cardiovascular health score			
		1st tertile	2nd tertile	3rd tertile	
	Score:0–12[a]	Score: 0–6	Score: 7–8	Score: 9–12	*p* value
N	906	244	365	297	
Covariates					
Female (%)	55.3	55.74	58.63	50.84	.132
Age (y)	74.0 ± 6.7	74.6 ± 6.8	74.1 ± 6.6	73.3 ± 6.6	.079
Education (y)	5.5 ± 3.3	5.5 ± 3.3	5.5 ± 3.1	5.6 ± 3.4	.943
Cognition impairment, (%)	23.4	25	23.84	21.55	.62
Depressed mood, $n = 900$ (%)	19.7	21.9	20.4	17.0	.323
Number of chronic diseases (%)					<.001
0	13.7	8.2	11.2	21.2	
1	35.0	23.4	40.0	38.4	
2	30.2	31.2	31.2	28.3	
≥3	21.1	37.3	17.5	12.1	
Outcome					
SPPB score, (IQR)	11 (10,12)	11 (8,12)	11 (10,12)	12 (11,12)	<.001
Poor physical function, %	24.2	35.2	24.9	14.1	<.001
Components of cardiovascular health					
Current smoker (%)	14.1	25.4	13.7	5.4	<.001
Physical activity (%)					<.001
Inactive	15.9	34.0	14.5	2.7	
Light active	44.3	52.1	51.0	29.6	
Active	39.9	13.9	34.5	67.7	
BMI (kg/m^2)	27.6 ± 4.0	29.6 ± 4.3	27.6 ± 3.9	25.8 ± 3.1	<.001
Mediterranean diet score	4.5 ± 1.6	3.7 ± 1.6	4.4 ± 1.5	5.2 ± 1.4	<.001
Total cholesterol (mg/dL)	220 ± 38.9	235 ± 39.4	223 ± 35.1	203 ± 36.6	<.001
Systolic blood pressure (mm Hg)	151 ± 19.5	155 ± 17.1	152 ± 18.9	145 ± 20.8	<.001
Diastolic blood pressure (mm Hg)	84.2 ± 8.6	85.6 ± 7.8	84.7 ± 8.5	82.3 ± 9.1	<.001
Fasting Plasma Glucose (mg/dL)	89 (82, 100)	101 (87, 122)	88 (81, 97)	86 (80, 92)	<.001

Note: BMI = body mass index; IQR = Interquartile range; *SD* = standard deviation; SPPB = Short Performance Physical Battery. Data reported as means ± *SD*, median, IQR, and percentage.

[a]The overall cardiovascular health score in this cohort ranged from 0 to 12.

Table 2. OR and 95% CI of Poor Physical Function (SPPB Score < 10) for Overall Cardiovascular Score, Among InCHIANTI Participants Aged 65 years and Older at Baseline

	Model 1[a]		Model 2[b]	
Overall CVH score	OR (95% CI)	*p* value	OR (95% CI)	*p* value
Per 1 point increase	0.75 (0.67–0.83)	<.001	0.76 (0.69–0.85)	<.001
Tertile score				
0–6	1.00		1.00	
7–8	0.55 (0.36–0.83)	.004	0.57 (0.37–0.87)	.010
9–12	0.28 (0.17–0.46)	<.001	0.31 (0.18–0.52)	<.001

Note: CI = confidence interval; CVH = cardiovascular health; OR = odds ratio; SPPB = Short Performance Physical Battery.
[a]Model 1 adjusted for age and sex only; [b]Model 2 adjusted for sex, age, years of education, impaired cognition, depressed mood, and presence of chronic disease.

odds of poor physical function ($p < .001$). A graded inverse association was also observed for tertiles of overall CVH and odds of poor physical function. Compared to the lowest tertile of CVH, 43% ($p = .01$) and 69% ($p < .001$) lower odds of poor physical function were demonstrated among participants in the 2nd and 3rd tertiles, respectively.

Similar to the results at baseline, there were statistically significant, inverse associations between overall CVH (modeled on a continuous and categorical scale) and poor physical function over the 9-year follow-up period (Table 3). For the fully adjusted models, compared to the lowest tertile of CVH score, the odds of poor physical function were 47% and 63% lower (all $p < .001$) for the 2nd and 3rd tertile, respectively. In addition, among health behaviors, adherence to ideal levels (compared to poor) for physical activity (OR = 0.22, $p < .001$) was strongly associated with poor physical function, followed by diet quality (OR = 0.63, $p = .009$) and BMI (OR = 0.66, $p = .032$). Among the health factors, only adherence to ideal levels of fasting plasma glucose (OR = 0.52, $p = .011$), was significantly associated with poor physical function.

When specific components of the SPPB test were examined, overall CVH appeared to be related more with walking speed and chair stands than balance (Supplementary Table 2). We also assessed health behaviors and factors separately and found statistically significant, inverse associations between health behavior scores and physical function across 9 years (Supplementary Table 3). No associations were observed for health factors.

In sensitivity analysis excluding participants with a baseline history of stroke and heart failure, the inverse associations between overall CVH score and physical function at baseline and over 9 years remained statistically significant (data not shown). Additionally, analyses using mixed effects models resulted in similar findings as the GEE model (Supplementary Table 4).

Discussion

In a cohort of community dwelling men and women 65 years and older, a summary score, based on four health behaviors (smoking status, physical activity, BMI, and diet quality) and three health factors (blood pressure, total cholesterol, and fasting plasma glucose), was used to characterize overall CVH. Participants with higher scores, indicating better CVH, demonstrated an inverse association with physical function over a 9-year follow-up, indicating that health behaviors and factors, even among older individuals are influential in maintaining physical functioning as they age. Additionally, health behaviors were more strongly and consistently associated with maintaining physical function.

While there have been several studies that have demonstrated protective associations between individual CVH score components and age-associated declines in physical function and mobility (10–16,31), it is important to examine the effect of overall cardiovascular wellness. Using summary measures of behavioral risk factors, Robinson et al. demonstrated the cross-sectional associations between the presence of three or four risk factors (smoking, low physical activity, obesity, and poor diet quality) with a three fold to five fold increased risk of poor self-reported physical function among older men and women. Similarly, Chakravarty et al. also showed that the presence of fewer behavioral risk factors (smoking, inactivity, and overweight) was associated with an 8 year delay of moderate disability among older individuals (8,9). In the Whitehall II study, the Framingham cardiovascular disease risk score (FRS) based on age, smoking status, systolic blood pressure, HDL- and total cholesterol, and diabetes status was assessed in a cohort of middle-aged men and women at baseline. After a follow-up period of 16 years, participants with a higher FRS indicating higher risk for cardiovascular disease, was associated with poor motor function (32).

Our findings suggest that even in older age, having ideal levels for health behaviors is crucial for maintaining physical function and preventing decline. Reasons for the lack of associations for health factors could be that given the relatively older age of the cohort, a larger proportion of the participants demonstrated intermediate or poor health for several of these (eg, blood pressure) (33), and additionally, some of the health behaviors may directly influence health factors. Amongst the health behaviors, physical activity emerged as the most important contributor to the protective associations observed for the overall CVH score. This is not surprising, since physical activity in older age may have several beneficial effects including improved muscle strength and mass (34,35), which are directly associated with physical function. Given our findings on the relative importance of health behaviors versus health factors, potential strategies should focus on promoting regular physical activity and improving diet quality for maintaining physical function in individuals as they age.

A significant strength of our study is its longitudinal design that enabled us to assess the relationship of overall CVH at baseline and poor lower extremity function over 9 years of follow-up. Additionally, information on health factors and behaviors in the study was collected using standardized and validated questionnaires and methods. Physical function in the cohort was examined using a performance based test, SPPB, which is a significant improvement to self-report and may better reflect physical function status (36). We were also able to adjust for the major covariates and confounders including cognitive status which also strengthens our findings.

Table 3. OR and 95% CI using GEE Estimates of Poor Physical Function (SPPB Score < 10) Over 9-year Follow-up for Baseline Overall CVH Score and Its Components Among InCHIANTI Participants Aged 65 years and older[a]

	Model 1[b]		Model 2[c]	
	OR (95% CI)	*p* value	OR (95% CI)	*p* value
Overall CVH score				
Per 1 point increase	0.78 (0.72–0.84)	<.001	0.78 (0.73–0.85)	<.001
Tertile score				
0–6	1.00		1.00	
7–8	0.52 (0.38–0.71)	<.001	0.53 (0.38–0.72)	<.001
9–12	0.35 (0.25–0.50)	<.001	0.37 (0.26–0.52)	<.001
Smoking status				
Poor	1.00		1.00	
Intermediate	0.66 (0.42–1.02)	.061	0.65 (0.42–1.01)	.055
Ideal	0.79 (0.53–1.18)	.256	0.72 (0.48–1.09)	.119
Physical activity				
Poor	1.00		1.00	
Intermediate	0.35 (0.24–0.51)	<.001	0.40 (0.27–0.59)	<.001
Ideal	0.18 (0.12–0.28)	<.001	0.22 (0.14–0.33)	<.001
Body mass index				
Poor	1.00		1.00	
Intermediate	0.76 (0.55–1.06)	.104	0.75 (0.54–1.04)	.085
Ideal	0.71 (0.49–1.03)	.074	0.66 (0.45–0.97)	.032
Diet quality				
Poor	1.00		1.00	
Intermediate	0.79 (0.58–1.08)	.144	0.81 (0.59–1.11)	.185
Ideal	0.61 (0.43–0.86)	.005	0.63 (0.45–0.89)	.009
Total cholesterol				
Poor	1.00		1.00	
Intermediate	1.26 (0.92–1.71)	.144	1.19 (0.88–1.63)	.262
Ideal	1.16 (0.81–1.66)	.412	1.07 (0.75–1.53)	.719
Blood pressure				
Poor	1.00		1.00	
Intermediate	0.74 (0.52–1.07)	.11	0.81 (0.56–1.19)	.29
Ideal	0.78 (0.23–2.72)	.699	0.88 (0.24–3.26)	.851
Fasting glucose				
Poor	1.00		1.00	
Intermediate	0.44 (0.25–0.76)	.003	0.47 (0.27–0.82)	.008
Ideal	0.49 (0.31–0.79)	.004	0.52 (0.32–0.86)	.011

Note: CI = confidence interval; CVH = cardiovascular health; GEE = generalized estimating equations; OR = odds ratio; SPPB = Short Performance Physical Battery.

[a]Individual CVH components were mutually adjusted; [b]Model 1 adjusted for age and sex only; [c]Model 2 adjusted for sex, age, years of education, impaired cognition, depressed mood, and presence of chronic disease.

Our study also has some limitations. The sample size of our cohort was relatively small (N = 906 at baseline). About 15% participants who were free of dementia (an exclusion criteria since several of the health behaviors were based on self-report) had missing data on baseline SPPB or health behaviors or factors. These participants were relatively older, had lower daily energy intake, more likely to have impaired cognition, and Activities and Instrumental Activities of Daily Living disabilities (Supplementary Table 5). Given this, we conducted sensitivity analysis using weighted GEE models assigning a probability of being missing and up-weighting the sample at follow-up to more closely match the sample at the baseline visit to assess the impact of missing data on our analysis, and results were similar to the standard GEE models (data not shown). Additionally, a large proportion of the participants (49% of those at baseline) were missing SPPB information at the 9-year follow-up visit, out of whom 57% died. Baseline overall CVH scores for these participants indicated that they had significantly lower scores on CVH components and SPPB scores (Supplementary Table 6) suggesting that we may be underestimating the true associations between physical function and overall CVH.

In conclusion, among older individuals, better CVH was associated with a lower risk of poor physical function cross-sectionally and over a 9-year follow-up. However, CVH was not a sum of its parts; and health behaviors, particularly physical activity exhibited stronger and more consistent protective associations. Therefore, while adherence to ideal levels of health behaviors and factors is important for preventing declines in physical function, an emphasis on health behaviors is vital for maintaining the quality of life in the elderly. While our findings need to be confirmed by other prospective longitudinal investigations, our results indicate that better overall CVH, operationalized using the AHA's LS7 metric, plays a significant role in preventing age-related functional declines.

Supplementary Material

Supplementary data are available at *The Journals of Gerontology, Series A: Biological Sciences and Medical Sciences* online.

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Conflict of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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